MEMS Reliability Assurance Activities at JPL

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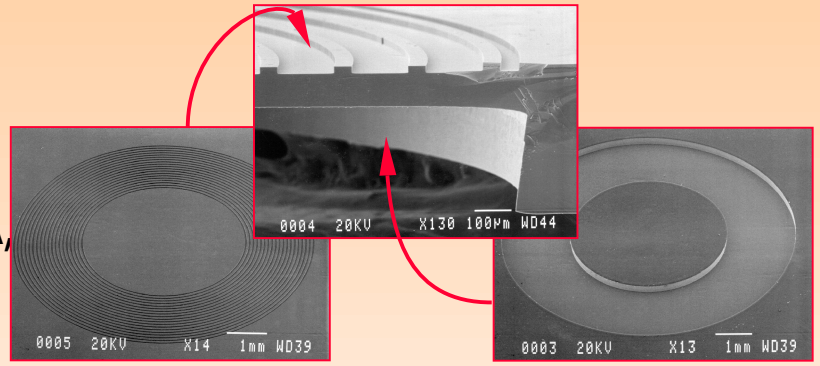
Outline

- MEMS Capabilities at JPL
- Overview of MEMS Reliability Assurance and qualification activities at JPL
- Current MEMS Reliability Activities
- MEMS Reliability Assurance Guideline for Space Applications
- Future Plans and Near Term Activities
- Summary

MEMS Capabilities at JPL

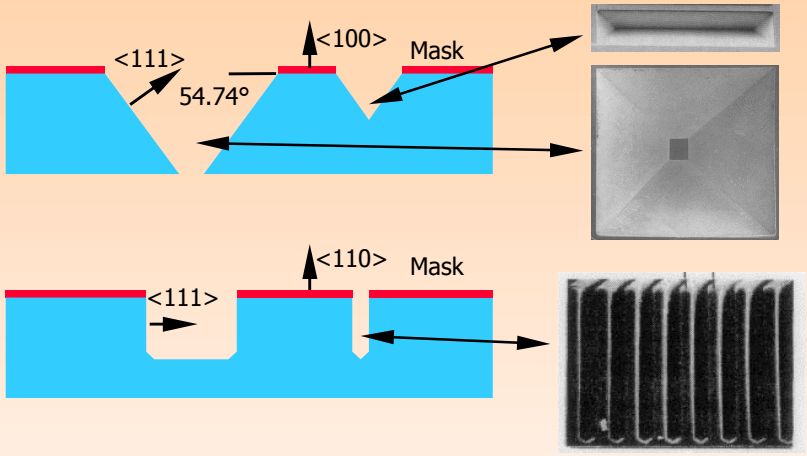
- **Design, Analysis and Fabrication**
  - Design - MSC/PATRAN
  - Layout - Tanner Tools
  - ANSOFT/Maxwell 3D Field Solver
  - Surface μmachining, Bulk μmachining, LIGA, Wafer Bonding, Deep RIE
- **Reliability and Failure Analysis**
  - Process Characterization
  - Test Structure Analysis
  - SEM, ESEM, Metrology, IR , Novel Visualization Techniques
- **Environmental Test & Characterization**
- **Radiation Test and Characterization**
  - Total Ionizing Dose
  - Single Event Effects



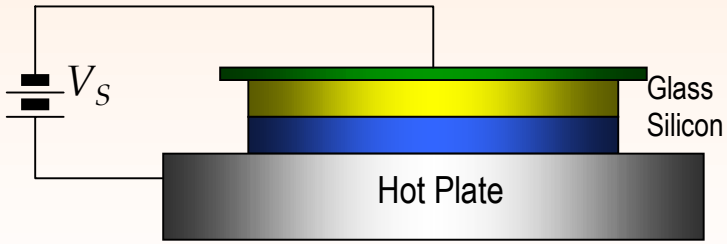
Micro-Valve

Quadrupole Mass Filter

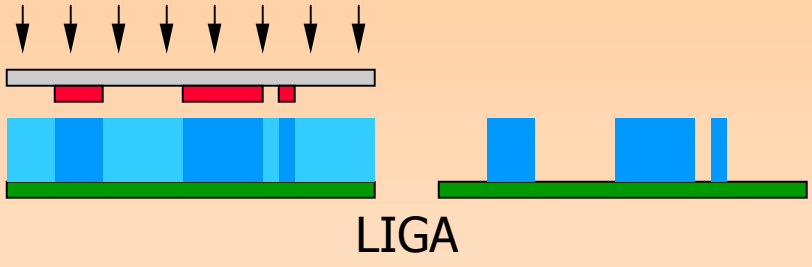
MEMS Fabrication at JPL



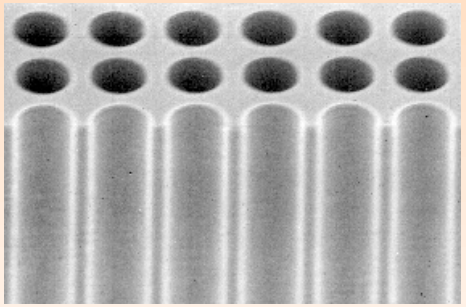
Anisotropic Bulk Micromachining



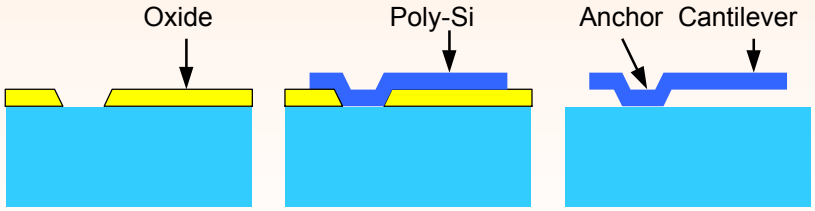
Anodic Wafer Bonding



LIGA



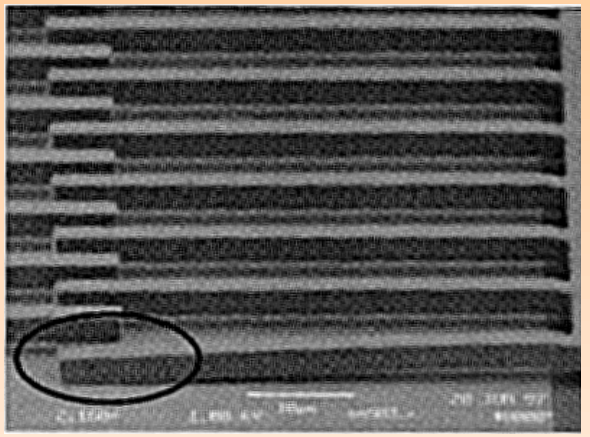
Deep Reactive-Ion Etching of Si



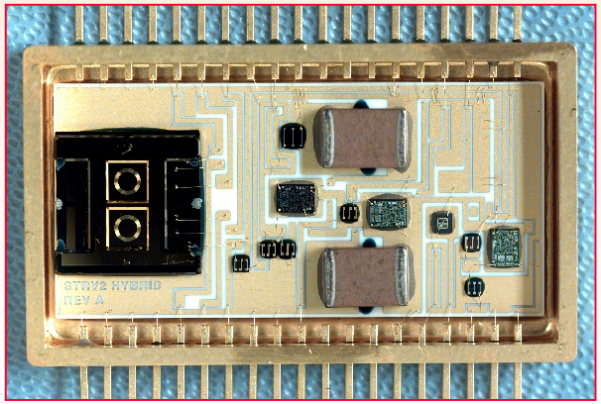
Polysilicon Surface Micromachining

MEMS Reliability Thrust Areas At JPL

- Process Characterization
- Environmental Test and Characterization
- Identification of Failure Modes and Mechanisms
- Qualification for Space Flight Applications
- MEMS Reliability Alliance



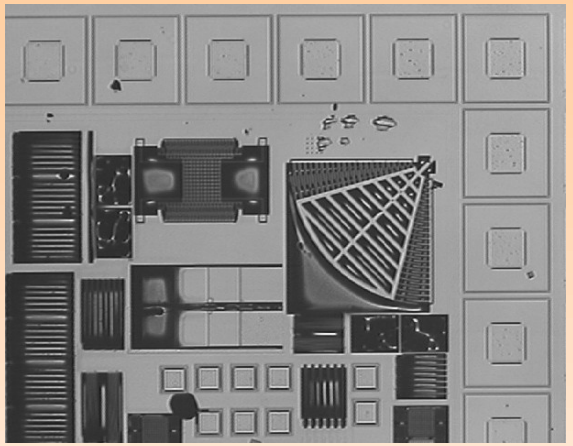
Polysilicon cantilever adhering to substrate



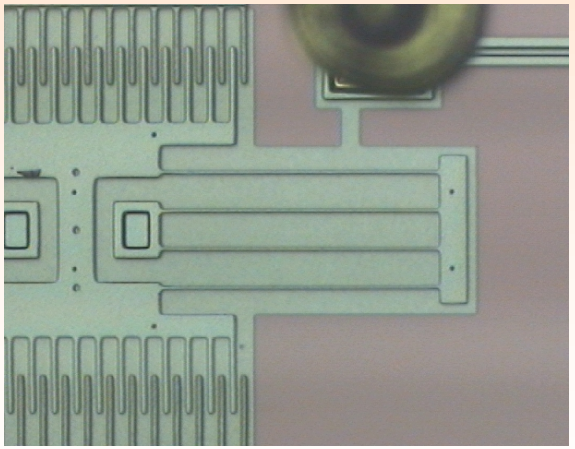
Tunneling Accelerometer on STRV-2

Process Characterization

- Utilize Reliability and Process Monitor Test Structures to Determine:
  - Process Stability and Uniformity
  - Crack Initiation and Propagation
  - Effects of Post Release and Packaging
  - Potential Failure Modes and Mechanisms



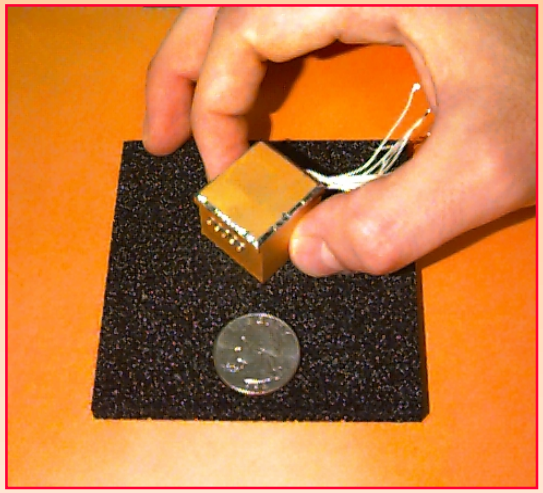
Crack Propagation Test Structure HP MOSIS



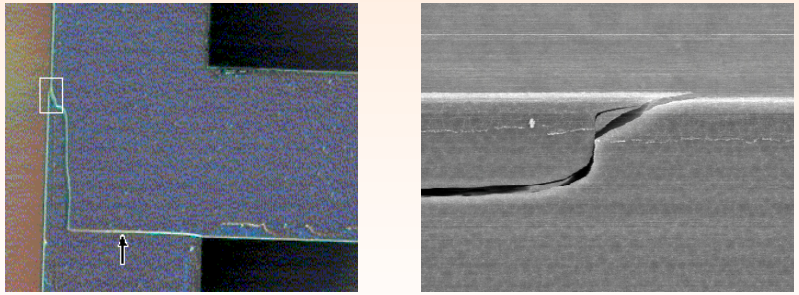
Electrostatic Comb Drive MCNC

Environmental Characterization

- Demonstrate the Reliability of a Design and the Suitability for the Intended Application
- Simulate the Launch Environment and Qualify the Design for Launch and In-Service Conditions



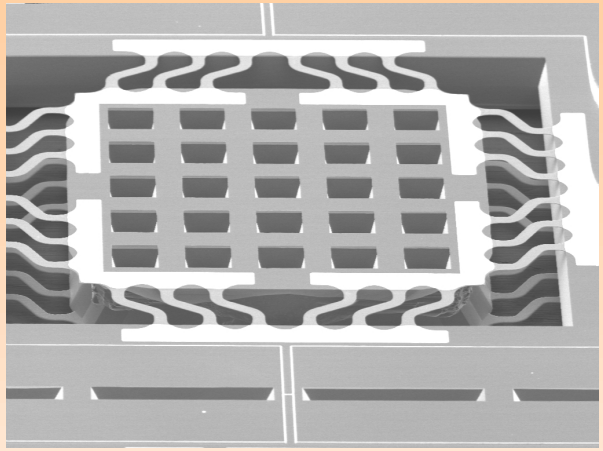
Micro Gyroscope



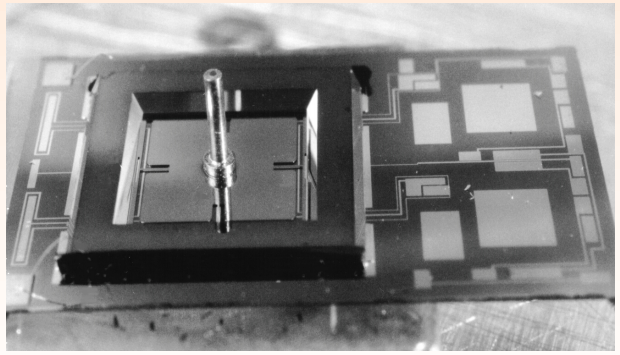
Cracks in single crystal silicon support beams caused by vibrations from a launch test

Current Reliability Activities

- Test Structure Characterization
  - MCNC MUMPS
  - HP MOSIS
  - ORBIT
- Device Characterization and Qualification
  - Microgyro
  - Magnetometer
  - Quadrupole Mass Spectrometer
  - Tunneling Accelerometer
- MEMS Reliability and Qualification Workshops (2 @ JPL, SPIE, IEEE)
- MEMS Reliability Assurance Guideline for Space Applications
- MEMS Reliability Alliance

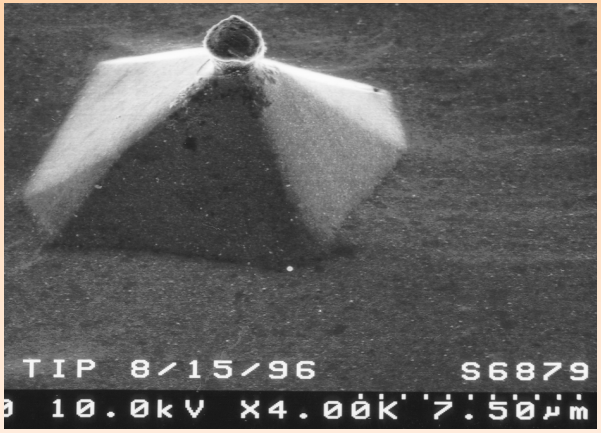


MEMS Accelerometer CIT

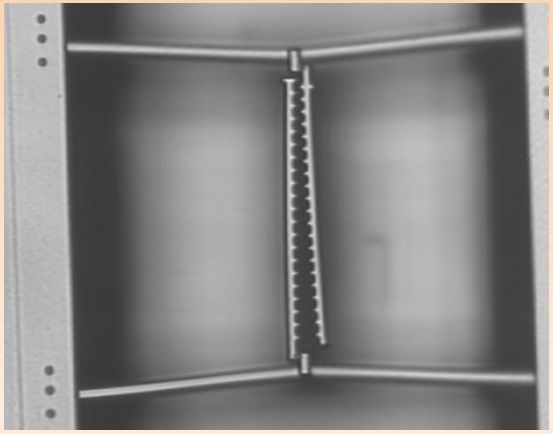


MEMS Microgyro

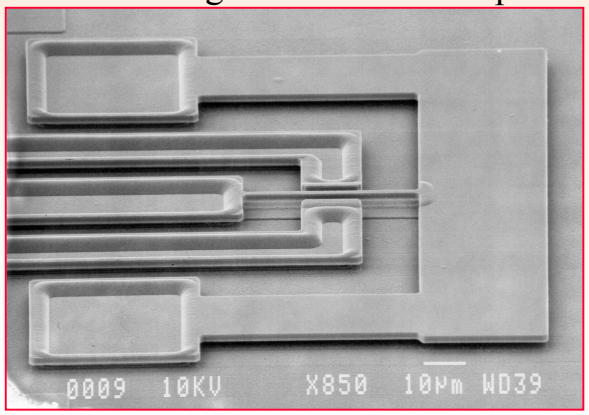
Process & Test Structure Characterization



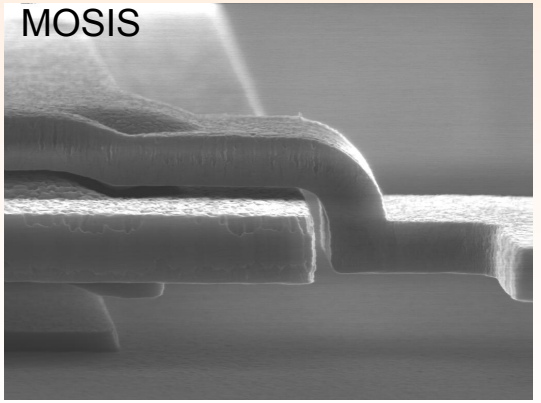
Tunneling Accelerometer Tip



Vernier Test Structure HP MOSIS

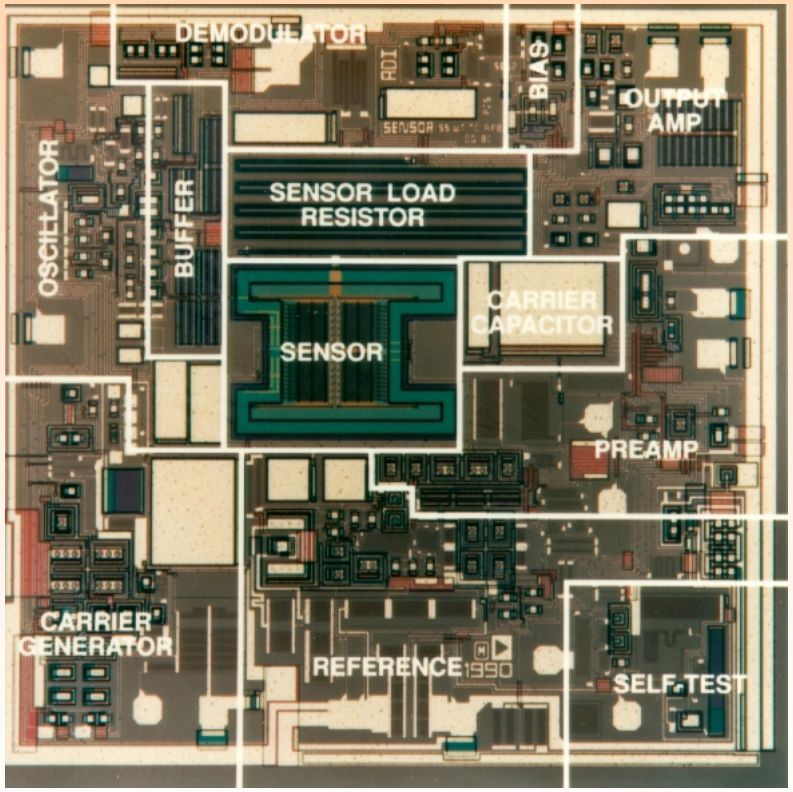


Temperature-insensitive resonator (U of M)

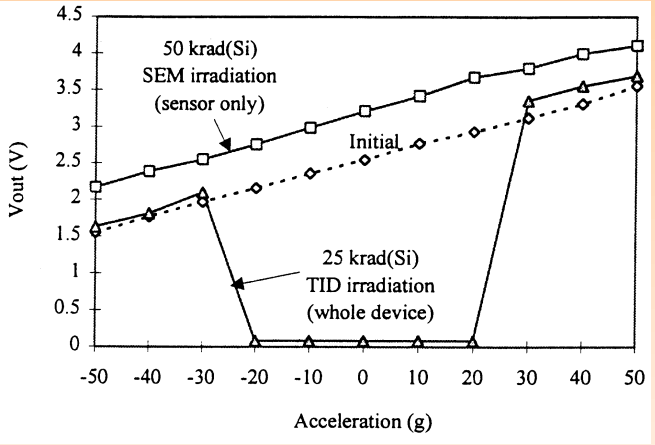


Polysilicon cantilever ORBIT

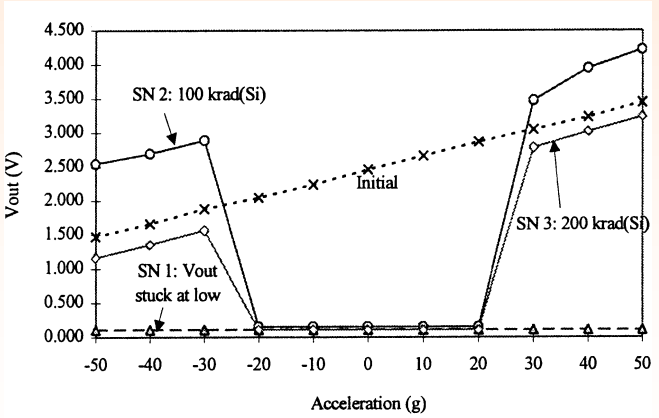
Radiation Effects—Total Dose Effects on ADXL50



Electron Irradiation

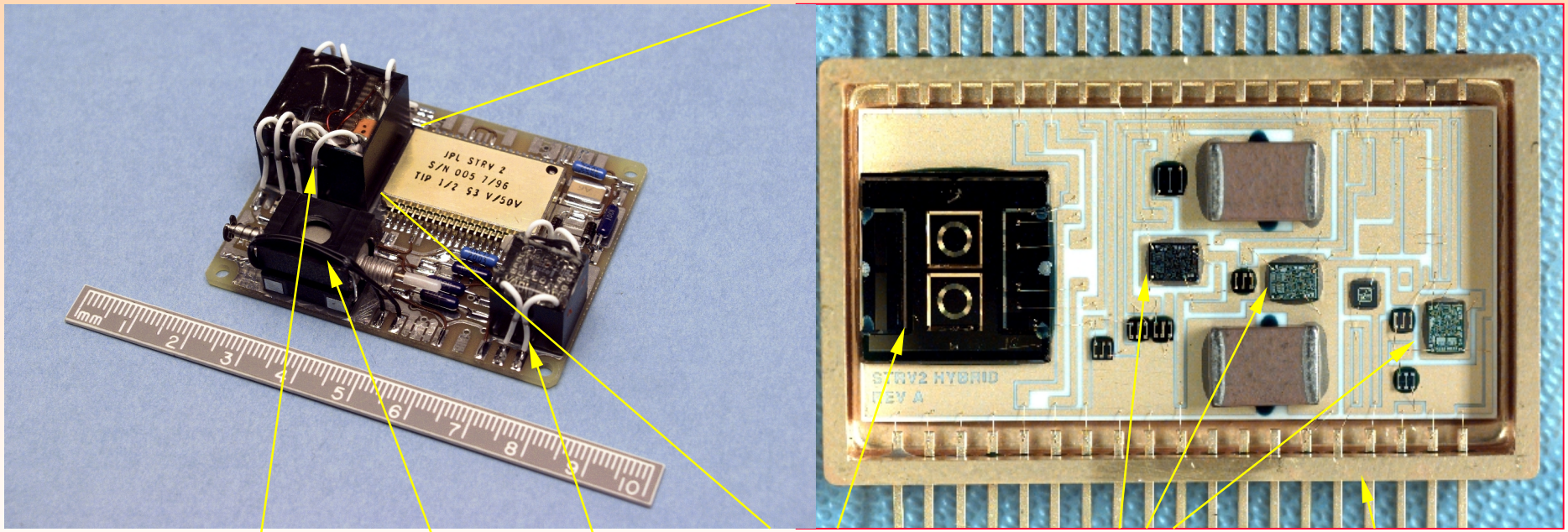


Proton Irradiation



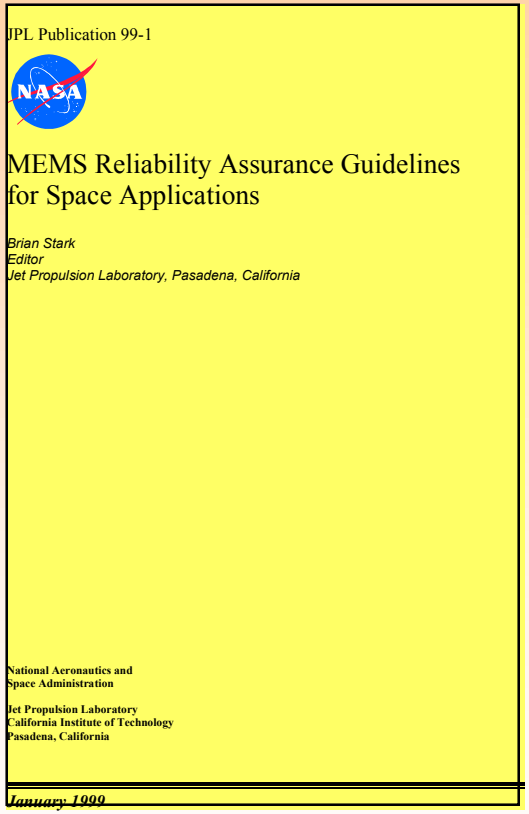
Flight Validation—Tunneling Accelerometer

Collaboration with Phillips Lab on the *Space Technology Research Vehicle* (STRV-2), launched in '98, to a 410 km x 1,750 km elliptical orbit



MEMS Reliability Assurance Guideline

- Developed as an aid to help in the understanding of MEMS reliability.
- Structured as an educational tool with detailed description of common structures and technologies.
- Material properties, failure mechanisms, and processing techniques are Addressed
- Device structures, and packaging techniques common to MEMS are Also Addressed.
- Provides for the development of suitable qualification plans.


JPL Publication 99-1

MEMS Reliability Assurance Guidelines for Space Applications

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MEMS Reliability Alliance

- An Organized Alliance of MEMS Development and Fabrication Government and Industry Laboratories Committed to the Development of Scientific Understanding and Improvement of MEMS Reliability in the Areas of:
  - Characterization and Analysis of MEMS Processes, Test Structures, and Devices
  - Development and Implementation of Novel Characterization and Modeling Tools
  - Improvement of Manufacturing Yield and Reliability
  - Identification and Analysis of MEMS Failure Mechanisms
- The Alliance will Provide for an Accelerated Infusion Path of MEMS Technology in High Reliability Applications
- Non-Proprietary Technical Information and Data will be Disseminated

Future Plans

- Continue to Utilize Test Structures for Characterization and Evaluation of Processes and Release Effects
- Implement In-Situ Testing of MEMS to Investigate Stiction using ESEM, AFM, and other Analysis Tools
- Continue Activities in the Characterization and Qualification of MEMS Devices for Space Application
- Expand the MEMS Reliability Alliance to Address Process Characterization and Validation of MEMS Models by Experimental Test

Summary

- MEMS Reliability at JPL Continues to be a Very Important Activity
- Evaluation of Process Monitors and Reliability Test Structures is Essential for Understanding Process Stability and Uniformity
- Specific Environmental Test and Characterization Techniques have been Utilized for Device Qualification and Application in High Reliability Systems
- The "MEMS Reliability Assurance Guideline for Space Applications" is a Useful Aid for Understanding Reliability and Qualification Issues and Possible Solutions
- Experimental Results will Continue to be Used for Process Improvements and Design Tool Validation
- The MEMS Reliability Alliance will Provide Significant Leveraging of Available Resources and Capabilities